CHALLENGES FOR CHILDREN’S PROSTHETIC FEET: KINETIC DATA FOR WALKING AND RUNNING IN REAL-WORLD LOCATIONS

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INTRODUCTION

Prosthetic foot design for children is challenging because children participate in a variety of locomotion activities. Optimizing a foot for walking will create deficiencies in running performance, typically in the manifestation of forefoot energy storing properties; while optimizing a foot for running will induce instability during standing and walking. The peak loads and loading rate children place on their prosthetic components during different activities has not been quantified in real worlds settings.

METHODS

Six transtibial amputees between the ages of 7 and 15 years of age participated in this study. Protocol was approved by the IRB. Children’s parents provided informed consent and participants gave assent to participate. A load cell (Europa, Orthocare Innovations, LLC) was placed in their existing prosthetic limb and transmitted force and moment data via Bluetooth to a laptop during the trials. Participants walked and ran on level ground and up and down 6° and 20° slopes. The participants completed between 12 and 54 trials over a 1-hour period. The goal of this project was to quantify the peak moments (Nm) and loading rate (Nm/s) to understand the strength requirements of children’s prosthetic components.

RESULTS

The highest sagittal moment values were approximately 100 Nm on the prosthetic limb (Figure 1). These positive values indicate considerable loading of the forefoot region of the prosthetic foot during walking on slopes and running.

Negative (dorsiflexor) moments varied more frequently across activities with -15 Nm the most substantial values. The loading rate of the forefoot region of the prosthetic foot reached 400 Nm/s.

DISCUSSION

A primary challenge for the design of a prosthetic device for children is the requirement that it performs well in both running and walking, and is able to endure the loads placed upon it without failure. Children have a tendency to break prosthetic feet at regular intervals and clearly place high stress loads on their limb system. The values from real world use in children indicate that the peak loads are one-fifth of the adult International Standards Organization (ISO) prosthetic foot standard, but the loading rate is double the adult ISO standard.

If strength and durability criteria are met, data about the transition between activities may aid in refining the control algorithm for a microprocessor-controlled (MPC) mesofluidic prosthetic foot-ankle. Altering the mechanical characteristics of the device are difficult to anticipate due to the spontaneity in activities of daily living for children – stability and stance is necessary in school and home settings, while running and playing may necessitate the system to emulate a highly compliant “blade” type prosthetic foot that is impractical for maneuvering and stability during standing or walking.

Due to the complexity of child locomotor activities, the controls algorithm needed to optimize a device must accurately identify each step and the type of locomotion activity. The implications of rapid loading and random load intervals challenge the mechanical design and controls algorithm. The ability to understand the walk-to-run transition and the intermittent nature of locomotor activities in children may be an integral component for the development of a high performance microprocessor foot with robust durability that is acceptable to children, parents, and prosthetists alike.

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DISCLOSURE

Christopher Villarosa is a student intern in the Biomechanics Laboratory at Orthocare Innovations, manufacturer of the Europa system. Michael Orendurff, Toshiki Kobayashi, Teri Rosenbaum-Chou, Wayne Daly and David Hensley are employees of Orthocare Innovations.

Figure 1: Kinetic data of the relationship between sagittal moments and stance duration for locomotor activities in transtibial amputee children.